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MULTI-SCALE PLANNING AND IMPLEMENTATION TO RESTORE FIRE ADAPTED ECOSYSTEMS, AND REDUCE RISK TO THE URBAN/WILDLAND INTERFACE IN THE BOX CREEK WATERSHED

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ABSTRACT
Multi-scale planning was used in the Upper Arkansas River subbasin and Box Creek watershed to prioritize and plan forest health and National Fire Plan restoration on San Isabel National Forest and Bureau of Land Management (BLM) lands. Restoration alternatives were designed to restore fire-adapted ecosystems, improve forest health, improve native species habitats, and reduce wildland fire and other risks to human communities. The Upper Arkansas River subbasin and Box Creek watershed are located in the mountains of central Colorado. National Forest and BLM plans and national policies and budgets identified the need to prioritize and plan to achieve effective multi-resource and fire adapted ecosystem restoration. A consistent and science-based approach was used for mapping and analysis of fire regime condition class, natural (historical) regime departure, vegetation, and other resource and social values. Findings from this analysis were used to determine the amount of area to restore, develop the management prescriptions, map operationally restorable outcomes, and conduct effects analysis. The results from the Box Creek watershed restoration project demonstrate a cost-effective and science-based attempt to provide consistent and repeatable risk data for assessment of conditions and development of alternatives. In addition, the interdisciplinary team demonstrated how to identify the full "decision space" available for restoration if an integrated approach to project prioritization, purpose and need, and proposed action formulation is implemented versus accepting the traditional "mitigation spin."

Keywords: fuel management, wildland urban interface, forest health, wildlife habitats, fire regimes, condition class, planning, natural regime.

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INTRODUCTION

The Box Creek watershed was identified as a priority for restoration in an assessment of all watersheds in the Upper Arkansas River subbasin of Colorado (McNicoll et al. 1999). This assessment used a systematic rating system combined with an interview approach for key publics to develop a suite of risk rankings for each watershed. This data was used to prioritize watersheds for restoration based on high departure from the natural regime, high risk fire regime (condition class 3), uncharacteristic levels of insect and disease, uncharacteristic wildlife habitats, conflicts between user groups, and high wildfire risk to the wildland urban interface. Uncharacteristic was defined as a vegetation-fuel condition, disturbance behavior or effects determined to not occur within the natural regime, similar to the definition from Hann (*this volume*). Funding for the planning and restoration implementation came from Forest Health and the National Fire Plan. The framework for the planning process was the document often referred to as the Cohesive Strategy, titled “protecting people and sustaining resources in fire-adapted ecosystems: a cohesive strategy” (USDA 2001) and the analysis of options for this strategy titled “fire and land management planning and implementation across multiple scales” (Hann and Bunnell 2001).

An important hypothesis related to planning processes was identified during the Upper Arkansas assessment and during the Box Creek watershed planning that we discuss in this paper. We hypothesized that truly integrated and prioritized approach using fire regime condition class, departure from the natural regime, and other science-based risk measures to prioritize project areas, develop the project purpose and need, design the proposed action, and involve the public would resolve many of the conflicts currently faced by agency leadership (USDA 2001, USGAO 2002). These conflicts include reduction in appeals and litigation from external public groups, regaining credibility with the public to treat wildlands, reduction in the need for mitigation (primarily reduction in treated area) to meet environmental laws and regulations (such as Endangered Species Act, Clean Air Act, Clean Water Act, Antiquities Act, Council for Environmental Quality regulations), and reduction of mitigations to achieve agency policy (such as Forest and Resource Plan standards and Manual Direction).

This integrated and prioritized process would be quite different from the current standard procedure. Currently, in the standard process, fire, fuels, or a resource staff identify the project area (often based on very limited criteria, inconsistent data, and ease of operations) and describe a conceptual purpose and need, then design the proposed action focused primarily on operational concerns, as well as achieving the most acres of treatment for least cost and highest commercial output or target output, irrespective of multi-resource laws, regulations, and policies. In response to this traditional approach, the interdisciplinary team evaluates the proposed action and recommends mitigation (usually reduced treatment area), which then develops into the final preferred alternative. Often, the remaining action alternatives emphasize one or more resource items (a “wildlife alternative” or a “watershed alternative”) that are unlikely to be implemented, and presented as a “range of alternatives” to meet requirements of NEPA. In contrast, we felt that the interdisciplinary integrated approach would prioritize those areas up front with the highest need for restoration.

Previous scientific assessments have found that most landscapes with high priority for restoration because of urban interface risk, fire exclusions, and a history of management not mimicking the natural regime typically lack high quality habitats and populations for wildlife and fish species of concern, old forest (old growth), and other critical issues (Hann et al. 1997, 1998, 2003). Consequently, a consistent and integrated science-based prioritization of areas for restoration will substantially reduce the potential conflict between restoration versus protection of high quality habitats and populations (Rieman et al. 2000). The reason that many projects continue to be proposed that conflict with high quality habitats and populations appears to either be because of lack of this type of prioritization or lack of up front design to reduce risk to habitats and populations. In the Upper Arkansas assessment where Box Creek was prioritized for restoration to improve habitats for big game, management indicator species, and lynx, as well as improve forest health and reduce risk to wildland urban interface, there was strong rationale for restoration and up front integrated project design for resolution of conflicts. For the integrated and prioritized approach, the purpose and need should provide rationale for the proposed action and identify the maximum area for treatment that would achieve the greatest and most cost-effective landscape reductions in risks to wildland urban interface, watersheds, wildlife habitats, and other objectives. In the context of this integrated and prioritized planning process all action alternatives would be equal in area and vary according to treatment methods.

This was found to be the case for the Box Creek planning process where all action alternatives were equal in area treated but varied according to selected treatment method. This non-traditional integrated design of alternatives; keeping the treatment area constant and varying the implementation tools (fire, mechanical and mix of fire and mechanical), was directly linked to the purpose and need that set forth the scientific basis for restoration. This process conceptually follows the framework and assumptions laid out by Hann and Bunnell (2001) for the Cohesive Strategy.

In the following sections of this paper we develop the results and discussion to summarize our findings in the management implications section and hopefully open and stimulate further discussion and work relative to the integrated restoration approach. The project focused on restoration of National Forest and Bureau of Land Management lands within the watershed in collaboration with the county soil conservation district, State lands, and private landowners. The watershed is approximately 9,700 hectares in size with about 7,300 hectares in federal ownership and about 2,400 hectares in private and state ownership.

STUDY AREA

The Upper Arkansas River subbasin is located in central Colorado southwest of Denver and east of Grand Junction. This is a long narrow river subbasin flowing generally north to south between the Sawatch Mountain Range of the Continental Divide to the west and the Mosquito Range to the east. The Box Creek watershed is a 6th code Subwatershed located in the northwest corner of the Upper Arkansas River subbasin (Fig. 1), to the southwest of the town of Leadville, south of the Halfmoon divide and north of the Twin Lakes divide. This watershed ranges in elevation from about 2,700 meters where Box Creek flows into the Arkansas River to well over 4,300 meters at the top of Mt. Elbert, the tallest peak in Colorado. Although this seems high in elevation, because of the southerly latitude of approximately 39 degrees, this area of the southern Rocky Mountains has similar vegetation zonation to elevations ranging from 1,800 meters to 3,000 meters in the northern Rocky Mountains at approximately 45 degrees latitude. Lower elevations of the Box Creek watershed along the river and primary stream drainages are sub-irrigated and covered with willows and wet meadows. Much of this type on private lands has been converted into hay ground and pastureland. Above these sub-irrigated lands mountain big sagebrush dominates the lower montane zone (Fig. 2) shifting into the montane zone, currently dominated by lodgepole pine, but historically dominated by a mixture of lodgepole pine with ponderosa pine and Douglas-fir. As elevations increase and on steep lower elevation north aspects, Engelmann spruce, subalpine fir, lodgepole pine, and subalpine meadows dominate the perspective. Above timberline, alpine tundra, talus, and rock occur from about 3,700 meters (12,000 feet) and higher in elevation. About two thirds of the watershed is in federal (National Forest, Bureau of Land Management) ownership and about one third in private and state ownership. Federal lands are non-wilderness with Forest and Resource plans emphasizing non-motorized primitive, big game winter range, and wildlife and fish (focus on management indicator species) habitat uses.

Nomadic Native Americans used the Upper Arkansas for summer and fall camps, hunting, and gathering. Buffalo, elk, and other large ungulates appear to have been common in the lower montane and montane zones. Fires were common, occurring from both lightning and Native American ignition, in the extensive fire maintained sagebrush grasslands and mixed conifer parklands of the lower montane and montane zones (Fig. 3). American and European exploration and settlement entered this area of the Upper Arkansas early in the 1800s (Griswold and Griswold 1996). Some exploration and settlement in southern portions of the Upper Arkansas subbasin (Buena Vista and Salida areas) had occurred earlier by Spaniards from Mexico, but the major influx of non-native Americans and Europeans occurred after 1850 into the early 1900s associated with the “Mining Era.” During this period extensive and intensive timber harvest occurred with multiple entries for structure logs and mill lumber; road and railroad punching, bridges, and tread; mine timbers; fuel wood for heating and for charcoal pits and kilns; and fuel wood for the large smelters. Historic logging for mine and other large timbers as well as mill lumber and structure logs focused on taking the larger trees (Engelmann spruce, Douglas-fir, ponderosa pine, and lodgepole). Focus on fuel wood was less specific regarding species or size.

Essentially the whole Box Creek watershed, which is within an approximate 32 kilometer radius of Leadville, was clearcut with multiple entries from lower to upper forest ecotones; except for a few scattered trees or groups of trees retained for shade or near structures, and a few patches of forest in very hard to access areas surrounded by very steep or rock terrain (Fig. 3). At the end of this period fuel wood was in such short supply that roots were pulled with teams of horses and hauled in with any remaining logs left on the ground from earlier entries (Dawson 2001). In addition, large herds of cattle, sheep, horses, mules, and burros were grazed to support the service industries (food, clothing, and freighting), as well as the mining and logging industries.

The impact from historic activities (burning, logging, mining, charcoal production, and grazing) was severe and extensive to the soil surface resulting in the loss of the surface soil horizon either through mixing with the subsurface on the gentle slopes or erosion into the streams and river on the steeper slopes. Most of the forest tree species seed source was lost as a result of burning and charcoal production except for lodgepole pine cones left on the ground. Since this was the dominant species and highly adapted to regenerate and grow in a mineral soil environment, lodgepole pine was the only species to regenerate. Very few ponderosa pine and Douglas-fir survived or regenerated in the Box Creek area. Field examinations determined that lack of these tree species was most likely due to the lack of available seed source and not a climatic change, since ponderosa pine appears to be slowly regenerating in the Box Creek area. Those remaining ponderosa pine and Douglas-fir were found primarily located on south exposures, although a limited number (less than 50) of mature seed bearing individuals have been observed within stands of lodgepole pine. With the loss of the ground fuel (grasses, twigs, litter, and small wood) and implementation of fire suppression, fires no longer occurred that would thin the lodgepole pine. This tree species now covers the landscape like a carpet, but with a steadily increasing load of ground fuel (Fig. 2).

The mid 1900s to current is characterized by a “rural” lifestyle that has transitioned from a post-mining era ranching dominated economy to a current recreation, water, and ranching economy. Recreational dispersed use, mining, hiking, mountain biking, skiing, hunting, and trail riding are many of the important uses of the public lands. Public fuel wood, post and pole operations, and saw logs are in demand. The Mt. Elbert conduit, Twin Lakes and Turquoise Lake reservoirs and other water developments provide local irrigation water and water to the Rocky Mountain Front from Denver south to Colorado Springs and Pueblo, and to the east into the Lower Arkansas River subbasins. Considerable subdivision of large ranches has occurred making the wildland urban interface a substantial issue. Fire suppression has been effective to-date in reducing the risk of large fires, but increasing fuel accumulations combined with the increasing effects from cumulative drought and the wildland urban interface tax effectiveness.

METHODS

Analysis Process

The framework for the methods follows the findings from Hann and Bunnell (2001) and methods follow those outlined by Hann (*this volume*). Definitions for natural fire regimes and their condition classes are provided in Tables 1 and 2 based on Hardy et al. 2001 and Schmidt et al. 2002. The first step after defining the project area, scope, and objectives was to review the available data in order to develop a process to map fire regime condition class (FRCC) and natural regime departure, and associated management implications and risk ratings for stand scale (4 to 20 ha) polygons. One of the most important map layers needed to achieve this objective was the potential vegetation map (Fig. 4), but of equal importance for determining current condition were the cover type and structure layers.

The Forest Service, Bureau of Land Management and State Forest Service vegetation data were not compatible due to differences in definitions, methods, and lack of complete coverage. The interdisciplinary team made the decision to use the 30 m remotely sensed cover type data (LANDSAT) as the base for building a compatible set of potential vegetation, cover type, and structure layers that could cover all lands within the Box Creek watershed. This decision was based on the interdisciplinary team's agreement that an integrated landscape planning process required a set of vegetation themes that could be used to determine fire regime condition class, habitat conditions, and other values and be consistent and compatible for all land ownerships across the watershed. The Forest Service local Resource Information System (RIS) contained information at the stand level for cover type, habitat type and structure. This information was used in combination with digital orthophotographs to extrapolate structure to similar stands missing structure attributes.

A very coarse scale Pike and San Isabel National Forest landtype association map was used as a surrogate for potential vegetation because the National Forest did not have a mapped classification for potential vegetation (habitat types). The landtype associations accounted for the main elevation zones of valley montane, lower montane, montane, subalpine, and alpine, but this map did not account for aspect differences that cause stand scale changes in potential vegetation. A rule set based on stand elevation and aspect was then developed to map potential vegetation for all ownerships. A key decision was made that identified the 30-meter remote sensing cover type map as the "true" or primary layer because it appeared to have finer scale and more accurate mapping. This meant that other attributes (structure and potential vegetation) would be adjusted to provide logical combinations with the cover type map. From this initial triplicate combination we conducted ground reconnaissance transects across elevation gradients to develop rule sets to refine the map attributes and correct illogical combinations of the current cover type, structure and potential vegetation. At the same time we adjusted the canopy closure and tree size class and assigned all data to the single vegetation map polygon layer.

In reviewing other planning projects we have found that this process of creating a single vegetation map layer with attributes that all interdisciplinary members will use throughout the planning process is often a major stumbling block. The time required to create, ground truth and adjust the map layer (4 weeks) was an important investment and prevents the traditional approach of using "what ever is available." Usually, "what ever is available" cannot be used across multiple scales, is incomplete (does not describe private or other agency areas within the project boundary), and results in inaccurate and incompatible departure and fire regime condition class calculations, and associated cumulative effects analysis.

A second key step was to simulate the natural regime to determine the average composition of vegetation classes and amounts of disturbance. For this we used the vegetation development dynamics tool (VDDT) (Beukema and Kurz 2000) and the box model framework (Hann *this volume*). We customized this framework for the potential vegetation types of the Box Creek watershed and conducted ground reconnaissance to determine succession rates and the historical fire frequency (Fig. 5). In the montane zone no live trees could be found with historical fire scars, but many stumps of lodgepole pine cut during the mining era had multiple fire scars and could be aged (Fig. 6). A few remaining short snags of ponderosa pine were also found that had multiple scars and also could be aged. By reconstructing a reconnaissance style watershed fire history combined with sensitivity testing of the simulation model we concluded that the area historically had frequent (approximately 30 year average) fire with highly variable patch size and periodicity in the montane zone for any given point in the landscape (Fig. 7). Most fires appeared to burn in the understory (surface), but torch out scattered groups if ladder fuels existed, forming a mixed fire severity. This maintained a very open forest of scattered individual large ponderosa pine and Douglas-fir intermingled with scattered groups of moderate size lodgepole pine. While the ponderosa pine and Douglas-fir could survive many fire scars, the lodgepole pine only appears to have survived up to about three fire scars.

In the subalpine zone the lodgepole pine also had multiple fire scar evidence as well as a few single scars on Engelmann spruce. Using a similar process as for the montane zone we concluded that the area historically had infrequent (approximately 60 year average) fire with fires of a larger size ranging from 40 ha to 1,000 ha (Fig. 7). However, contrary to the traditional view of crown fire replacement in the subalpine zone, this area appears to have had a mixed fire severity that burned as a surface fire through much of the lodgepole pine and torching out groups of lodgepole pine, Engelmann spruce, and subalpine fir where ladder and down fuels existed. There is little doubt that if we would have used the textbook literature on fire frequency and severity, rather than conducting the simulation modeling combined with ground reconnaissance, we would have misclassified both the montane and subalpine zones into the infrequent replacement class, rather than frequent mixed for the montane zone and infrequent mixed class for the subalpine zone.

We could find little evidence to classify the fire regime in the lower montane sagebrush zone and the valley montane riparian zone, due to the extensive and intensive disturbance that has occurred in these areas from the mining era to the current period. Because of the large fine fuel component (grass) that would have occurred historically we assumed that the fire frequency was similar to that of the montane zone and that fire severity was replacement or mixed.

The current composition for cover type and structure were then determined and compared to the natural averages following the methods defined by Hann (*this volume*). Similarity of current to natural, departure, fire regime condition class, management implications, and risk ratings were calculated and assigned. Other current data for resources, social, and economic indicators, along with operational variables (such as road access, distance to private structures, adjacent fuel risks) were also summarized for the watershed.

Planning Process

To test our comparison of the integrated and prioritized planning process used for the Box Creek project against a number of recent project environmental assessments (EAs) developed using the traditional single purpose with operational focus we used a rating system to assess the strength, continuity, and consistency of prioritization, purpose and need, action alternative formulation, and effects analysis. In addition, related project information relative to appeals, outcomes for the final decision, and lawsuits were reviewed. Informal interviews were conducted with selected agency interdisciplinary, environmental, and other involved group members to determine satisfaction, dissatisfaction, and amount of support for the different projects. Similar observations and interviews were conducted during the Box Creek project in order to make a qualitative comparison of the success of the two different planning processes.

RESULTS

Analysis Process

Current vegetation information (potential vegetation, cover type and structure) was summarized to the successional classes for each potential vegetation type (PVT) as described by Hann (*this volume*) (Tables 4 and 5). In the montane PVT only 12 percent was found to fit the stand conditions characteristic of the natural regime, while 88 percent where uncharacteristic of historical stand conditions (Table 6). This lack of characteristic conditions was primarily related to the mining era logging combined with the exclusion of fire and the subsequent excessive development of dwarf mistletoe. The mining era logging alone would have caused a substantial change in conditions, but if fire would have continued to play its natural role after the mining era logging the regenerating lodgepole pine would have been thinned and developed a much higher diversity of size classes, tree groups, and patches. Patch size diversity would have controlled the spread of dwarf mistletoe. It is likely that in this fire affected mosaic, ponderosa pine and Douglas-fir could have regenerated, but because of the dense lodgepole pine cover and litter/duff these species could not compete. Although 12 percent were similar in structure and composition to stands that occurred historically, only 10 percent were similar in composition. This occurred because there was twice as much of the mid development closed (4 percent versus 2 percent) conditions.

Within the characteristic classes a limited number of aspen stands of small area (< 0.5%) occurred in the early development successional stage (A). Stands in this class were identified as aspen seedlings intermingled with shrubs and herbaceous species. This lack of the early development stage was due to the exclusion of the tree group replacement effects of the mixed fire regime. Historically there was about 8 percent of the montane PVT in this early stage. The only stands found to be characteristic of the mid development closed successional stage (B) were closed pole and sapling aspen with shrub, herbaceous, and lodgepole pine seedling understory, which accounted for about four percent of the area, which was about twice the amount that occurred historically. Only about 1 percent of the area was found to be in the open (C) stage all of pole and sapling tree size, also with an aspen/conifer cover type. Historically this class occupied about 16 percent of the area and was dominated by the lodgepole pine with scattered ponderosa pine and Douglas-fir cover type. The loss of this type has occurred because of loss of historical surface fires that opened up the closed class (B) or thinned regeneration in the early development class (A).

Approximately 7 percent of the characteristic open late development class (D) still occurs with mature size class of lodgepole pine and large scattered ponderosa pine and Douglas-fir, mostly on southerly aspects with dry soils at the southern boundary of the watershed where proximity to Twin Lakes, an historically important recreation area, may have constrained logging activities. In addition these dryer soils appear to have slower regeneration and closure than more moist stands to the north. This area also receives higher winds that may have reduced efficacy of surface fire suppression during the early 1900s. The historical Box Creek montane landscape was dominated by this class (66 percent), which was maintained by mixed fires that burned on the surface through open areas of larger lodgepole pine that contained scattered ponderosa pine and Douglas-fir, and crowned into the denser tree groups. No stands were currently classified as characteristic of the late development closed (class E) successional stage of old tree size and age dominated by either aspen or lodgepole with scattered ponderosa pine and Douglas-fir. Almost 8 percent of the montane PVT occurred in this type historically, generally in the more moist draws where mixed fires were of a more creeping nature that thinned smaller trees, consumed ground fuels, and opened small patches, but retained a closed canopy of larger trees.

Most of the current Box Creek montane PVT occurs in an uncharacteristic condition (90 percent) as a result of the mining era logging followed by fire exclusion and spread of dwarf mistletoe. The major uncharacteristic condition that occurred in this PVT was stand conditions dominated by dwarf mistletoe infected mature, pole, and sapling size trees with a lack of understory shrubs and herbs, thin to moderate litter and duff, lack of scattered ponderosa pine and Douglas-fir, and lack of large snags or down logs (class L). However, much of the area (11 percent) was also classified as having uncharacteristic succession (class I) where dwarf mistletoe has not yet developed excessive levels and the primary effects relate to the mining era logging followed by fire exclusion. Most of these stands were closed, pole and sapling lodgepole pine, lacking any substantial litter and duff layer with little understory shrub or herbaceous vegetation. A small portion of the montane PVT (7 percent) that had been clearcut harvested in the past was classified as uncharacteristic timber management (class G) not mimicking the natural regime because of a lack of mixed conifer regeneration.

In the Subalpine PVT much more of the area (93 percent) was in stands characteristic of the historical or natural regime. However, the composition of the characteristic classes was only 40 percent similar because of a lack of the early development (A) and late development open and closed (D), and too much of the mid development open and closed (Table 7). This lack of a similar composition of stand conditions was a result of the exclusion of fire following the late 1800s and early 1900s regrowth after the mining era logging. Even given the impacts of the mining era logging this type is productive and would have recovered its natural composition if the mixed fire regime would have been allowed to play its natural role of thinning and creating a salt and pepper mosaic of early, mid, and late development open and closed stands. With an approximate 50-100 year fire cycle this type has missed an average of two cycles of mixed fire effects. However, this is too simplistic an approach to view the exclusion of fire from this regime. Although the average was found to be between 50-100 years this type was very variable in fires through time and space with more frequent fires of as short an interval as 20 years to less frequent fires of 130 years. The more frequent fires tended to occur on the southerly aspects, benches, and ridge tops, while the less frequent fires tended to occur on the northerly aspects and in the moist bottoms. Although the gross fire areas in this type may have been fairly large the areas that actually crowned appear to have been very salt and pepper in pattern and related to topography and the pre-fire fuel conditions. Exclusion of fire not only resulted in a loss of this salt and pepper pattern, but an increase in canopy density, understory tree layers, and down fuels.

A limited number of stands of small area (< 0.5%) did occur that fit the characteristic early development successional stage (A). Stands in this class were identified as Engelmann spruce and subalpine fir seedlings, lodgepole pine, or aspen intermingled with shrubs and herbaceous species. The shortage of this successional stage was a direct result of fire exclusion. An over abundance of stands and area (65 percent versus 16 percent) were found in the characteristic mid development closed successional stage (B) of closed pole and sapling lodgepole pine or aspen. This excess was directly related to lack of fire that thinned closed stands and created open patches, thus creating open stands with increased growth rates of the larger surviving trees followed by understory regeneration of Engelmann spruce and subalpine fir. In addition there may have been a lack of Engelmann spruce and subalpine fir seed source following the mining era logging that favored lodgepole, as well as an excess of aspen regenerating on disturbed soils. A similar but less dramatic trend (16 percent versus 13 percent) occurred in the mid development open (C) stage, all of pole and sapling tree size, dominated by lodgepole pine or aspen. This slight excess appears to be also related to the post mining era logging and fire exclusions for similar reasons as the closed stage. A very small number and area of stands (< 0.5%) with similar cover types occurred in the late development open (D) successional stage with mature size class. In contrast, a fair number and area of stands occurred in the characteristic late development closed (E) successional stage with old tree size and age dominated by aspen or lodgepole pine. The major uncharacteristic condition that occurred in this PVT was stand conditions determined to be beyond the successional maximum due to lack of mixed fire effects (I). These were typically dominated by moderate canopy closure of mature lodgepole pine or Engelmann spruce and subalpine fir that had a deep litter and duff layer with an understory of low to medium height shrub or herbaceous vegetation.

The current similarity of the Montane PVT to the natural regime was only 10 percent, indicating a 90 percent departure (Table 6). The standard breaks for each fire regime condition class and historical range of variability (HRV) departure class are 0-33 percent (classes 1 and low departure respectively), 34-66 percent (classes 2 and moderate departure respectively), and 67-100 percent (classes 3 and high departure respectively. The results for the Montane PVT placed this type in fire regime condition class 3 with high (H) departure. In contrast the current similarity of the subalpine PVT to the natural regime was 60 percent, indicating a 40 percent departure, which fits in fire regime condition class 2, and HRV departure class of moderate (M) (Table 7).

Current restoration management implications for the Montane PVT would be to manage to recruit the early development (A) and late development closed (E) classes, reduce the mid development closed class (B), retain and recruit the late development open class (D), and reduce the uncharacteristic classes (G, I, and L) (Table 6). The early development class could be fairly easily recruited through mechanical, fire, and planting treatments in the uncharacteristic classes (G, I, and L) by mimicking the mixed fire regime and managing for lodgepole pine, ponderosa pine, and Douglas-fir regeneration. If enough of the early development class (A) were created this would result in an increase in the mid development closed or open classes (B and C) within a fairly short time period (20-40 years). The closed stands (B) could then be thinned to produce more of the open stands (C) and promote growth of larger trees to late development stands that could be maintained in an open condition (D) with thinning or underburning. Thinning, planting, and underburning in uncharacteristic classes with mature trees (L and I) could recruit the late development open class (D). The late development closed class (E) could be developed within a somewhat longer time frame (30-50 years) after developing the late development open class (D) and allowing development of moderate to closed canopies, multiple layers, and old trees. Terrain plays an important role in the location of these late development closed stands. These types of conditions historically were in the bottoms and north aspect cooler conditions where the mixed fires typically burned around or crept through the litter and duff resulting in very low mortality of understory trees and only small gaps from torching of ladder fuels or windthrow.

The current high departure (90 percent) in similarity to the historical or natural regime and the large amount of uncharacteristic stand conditions (88 percent) result in substantial risks. These include potential for extreme wildfire behavior that could cause negative effects to both ecosystems and threaten the wildland urban interface. This large area of uncharacteristic habitats that lack composition, patch, structural, and snag and down log diversity have resulted in a lack of both quantity and quality wildlife habitats for management indicator species. The low diversity of plant species, depauperate understory, lack of down logs, and closed stand conditions result in high tie-up of nutrients in the stagnated tree canopies taking away nutrients from the soil system. The epidemic levels of dwarf mistletoe in lodgepole pine have created a “forest that is defenseless” (Steinke 2003) without the natural fire regime. The natural regime contained patches of endemic dwarf mistletoe that added to the natural diversity. However, currently the tables have turned and the epidemic level of dwarf mistletoe dominates the processes and reduces natural diversity.

Current restoration management implications for the Subalpine PVT would be to manage to recruit the early development class (A), retain and recruit more of the late development closed class (E), and reduce the mid development classes (B and C) and the uncharacteristic class (I). Recruitment of class A could be accomplished by mechanical, fire, and regeneration treatments for Engelmann spruce, subalpine fire, aspen, and lodgepole pine in the mid development closed class (B) or the uncharacteristic class (I) that mimic the natural regime. Similar reductions of the mid development closed class (B) and the uncharacteristic class (I) through thinning and underburning could result in more of the late development open class (D) within a 20 to 30 year time frame that could subsequently be allowed to close canopy and develop the multiple layers of a class E.

The current moderate departure (40 percent) in similarity to the natural regime and the relatively low amount of uncharacteristic stand conditions (7 percent) give the Subalpine PVT substantial opportunities for rapid restoration and maintenance of relatively good conditions. Most departure is due to a lack of balance in composition of the characteristic classes of A through E, particularly the lack of early development (A) and late development closed and open classes (E and D). Because of the lack of balance in composition of characteristic stand conditions, severe effects and risks to the wildland urban interface may occur from wildfires. This lack of balance also results in a lack of quality wildlife habitats, particularly for Canada lynx and their prey (snowshoe rabbit and red squirrel). Negative effects to soils and forest health occur at a moderate level to the overall landscape level, but not so much at the individual stand level. Thus the fire regime condition class is a 2 as compared to 3 for the montane PVT, and the HRV departure class is a moderate compared to high.

Although ground reconnaissance indicated little evidence that could be used to simulate the natural regime averages for successional stages and disturbances in the Lower Montane sagebrush PVT we were fairly confident in estimating its similarity to the natural regime at 65 percent with departure of 35 percent. Although this PVT was impacted substantially by grazing during the mining era it appears to have recovered a diversity of native species, sagebrush cover, and a surface soil conducive to herbaceous species. Lack of fire appears to be having a substantial effect in loss of sagebrush and grass patch diversity, sagebrush age diversity, and sagebrush canopy closure; thus our estimate of 35 percent departure. Our ground reconnaissance evaluation of sagebrush burns implemented more than 15 years ago suggest that application of fire in this type effectively increases grass and herbaceous diversity for several decades. For the riparian and alpine PVTs we were confident in estimating that their similarity was approximately 95 percent and departure only 5 percent.

Planning Process

Planning for the project to meet the National Environmental Policy Act (NEPA) was organized into five components.

1. Planning - the framework for planning linked multiple scales: 1) national and regional guidance, such as the Cohesive Strategy and T&E species conservation plans; 2) Forest and Resource Plans and the Upper Arkansas assessment (Fig. 1); and 3) project area conditions.
2. Data - in concert with planning the data was linked between all disciplines and scales so that inconsistencies between data sources did not occur. A key step in this process was the reconciliation of vegetation layers (cover type, structure, potential vegetation) for all land ownerships within the watershed. The base reference data for analyzing risk included understanding the natural regime, the natural fire regime map, and the classification of natural regime departure and fire regime condition class.
3. Desired condition (Fig. 8) - in development of the desired conditions that would occur following implementation of restoration the interdisciplinary team focused on identifying three components: 1) key landscape interconnections; 2) operationally restorable treatment units (Fig. 9 and 10); and 3) the range of prescriptions and tools.

4. Alternatives – in developing the alternatives the desired conditions and operational stands identified for treatment to achieve that desired condition were held constant for all action alternatives, ensuring that all action alternatives met the desired future condition. Differences between the action alternatives were focused on differences in tools (such as fire, mechanical, or mixes of the two).
5. Public support – in involving the public the knowledge and support for the project were cumulative because key public individuals and groups had prior knowledge and involvement in the Upper Arkansas assessment. They were not only informed of conditions during the assessment they were interviewed as to their knowledge and opinions on conditions and issues in the Upper Arkansas. Consequently, there were no surprises and generally common agreement that the Box Creek watershed was a good place to prioritize for restoration work. Some disagreement existed between those preferring commercial harvest versus those preferring non-commercial mechanical or burning, but these disagreements were resolved as they were involved in the operationally restorable tools discussion.

We found that a critical component to success of the planning process were the skills and relationships between the interdisciplinary team and decision maker. The interdisciplinary team leader required multi-resource and ecological knowledge and experience, an understanding of social climate and legal constraints, and capability to interact with specialists regarding selected tools. The interdisciplinary team core membership was key and was built on the premise that a highly energized, small (less than 4 members) core working group that has a good understanding of measures of natural regime departure, disturbance regimes, and multi-ecosystem functions was most effective. The interdisciplinary team workshops were condensed (4 to 5 days at a time) versus 1 or 2 day meetings spread out over 6 months to a year. This approach proved most effective in maintaining team energy, problem solving and production. From both interdisciplinary team and decision maker perspective it was critical that the purpose and need focused on restoration based on the analysis process and not on a predetermined acre, volume target, or type of treatment.

One of the interesting outcomes of the public involvement was our recognition of the high interest in actually helping us obtain historical photos and documentaries of conditions in the Box Creek watershed and the Upper Arkansas. There was much more interest in this aspect than in providing input on purpose and need, alternatives, or effects.

The interdisciplinary team developed the range of prescriptions with a focus on achieving the desired conditions for different operational situations (Table 9). Twenty-four prescriptions were developed that were mapped to each polygon within the project area and every hectare was assigned to a polygon. Prescription designs for reducing risk to wildland urban interface involved much more than assignment of a fuels reduction (thinning) prescription in the proximity of subdivision structures. The 275-meter (300 yard) fuel breaks would do little to protect these structures from mass running crown fire brands that would occur with high winds coming from the west. The landscape west and northwest of the subdivision area, for the width of the watershed, was given a mix of prescriptions that would shift fire behavior from a crown to a mixed or surface fire that would move slower, have lower intensity, and be much easier to contain.

In order to improve ecosystem and wildlife habitat conditions the interdisciplinary team designed a watershed-wide mosaic of prescriptions that would generally reduce departure from the natural regime. In addition, they developed prescriptions designed to promote or protect old growth, big game winter range, black-backed woodpeckers and yellow-bellied sapsuckers, marten, and Canada lynx to assure these management concerns were addressed. In addition treatments were scheduled and designed to reduce the negative effects of roads and improve overall habitat conditions.

Action alternatives developed into three differing mixes of tools (Table 7). Proposed or preferred action, harvest (mechanical) emphasis, and fire emphasis. All three alternatives treat similar amounts of area, but the harvest emphasis uses mechanical and commercial harvest where possible, while the fire emphasis uses fire wherever possible. In contrast, the preferred or proposed action mixes fire and harvest in what the interdisciplinary team agrees best achieves the risk reduction objectives. Part of each alternative is an aggressive plan to protect quality aspen stands and old trees and create conditions where natural process such as windthrow following treatment by fire will result in quality wildlife habitat (no post-treatment salvage). An additional component of all alternatives was to maintain areas previously treated to reduce mistletoe and improve structural diversity. The spatial arrangement of this mix of tools based on the prescriptions were developed and tested against the landscape connection criteria established to reduce risk to wildland urban interface, to ecosystems, and to habitats (Fig. 11).

A review of other similar planning projects that used the traditional single purpose with operation focus resulted in the emergence of several key issues:

1) Most traditional planning project areas were prioritized first on operational opportunities. The operational opportunities typically did not rigorously consider Forest, Resource, or Land Management plan standards and objectives, Agency Manual, or environmental law (NEPA, ESA, CAA, CWA, etc.) regulations. The consequences were a loss of credibility between the interdisciplinary team leader, decision maker and other staffs, environmental groups, regulatory agency staffs, and publics that a project would be proposed that would go against previous decisions and environmental regulations. In response Freedom of Information Act (FOIA), appeals, and lawsuits can result that use up substantial agency and interdisciplinary team energy. The subsequent result was typically the mitigation of the proposed action alternatives to meet standards, direction, and regulations, typically through reduction of treatment area, or failure of the project due to a lawsuit reversing the decision.
2) Most traditional planning project areas were prioritized and developed the purpose and need based on philosophical, conceptual, or subjective perceptions of fire regime condition class, forest health, fire, or other risks. The consequence was a lack of consistent and quantifiable information that could be used to provide context to broader extents (such as nation, region, state, ecoregion, or subbasin). In addition, communication among interdisciplinary team, the decision maker, and the publics were difficult because of lack of definition. Publics at a broader local scale (County, Subbasin) were not interviewed and felt left out. Similar consequences occur as for issue 1 relative to FOIA, appeals, lawsuits, and resulting mitigation or project failure.
3) Most traditional planning projects did not provide rationale as to the priority or the purpose and need that carried directly into the formulation of the action alternatives and analysis of effects. The consequences were a feeling by the public that the people leading the projects were “tinkering” without full knowledge of objectives and outcomes. Similar consequences occur as for issue 1 relative to FOIA, appeals, lawsuits, and resulting mitigation or project failure.

In contrast, our findings throughout the Box Creek planning process were that the integrated and prioritized approach using science-based measures of risk carried from the purpose and need through the alternatives and effects analysis generally resolved these issues by developing internal and external confidence. Of equal importance were the decisions by the decision makers not to predetermine the acre or volume target or the action alternative. The involved decision makers waited until the Upper Arkansas assessment was completed to prioritize Box Creek as a restoration project. Following this step they waited to assign targets or consider the proposed alternatives until after the interdisciplinary team with public involvement completed the analysis of fire regime condition class and departure, wildlife habitat and watershed conditions, resource and social values, estimated area needed to treat to restore, and developed management prescriptions, and subsequent preliminary proposed action alternatives. This allowed the interdisciplinary team and involved publics to integrate and design the most effective combination of treatments to achieve the purpose and need.

DISCUSSION

Analysis Process

Results for each PVT were summarized for the Box Creek watershed as a whole (Table 8). In order to achieve an objective of condition class 1 with low natural regime departure over the total project implementation period we calculated that we would need to treat approximately 1,550 to 1,650 ha within the Montane PVT, 700 to 800 ha in the Subalpine PVT, and 900 to 1,000 ha in the Lower Montane PVT. This resulted in a total of approximately 3,300 to 3,400 ha of treatment to achieve the objectives. Subtracting the desired departure from the current departure and multiplying times the area within the PVT calculated the area to treat to achieve the desired condition. A higher desired departure (20 percent) was allowed for the Montane PVT for this first phase of restoration because the interdisciplinary team did not feel a much larger area could be treated with fire or harvest and be economical or accepted socially. However, this desired departure was lower than that used by Hann and Strohm (2003) in order to move the PVT well into the middle of condition class 1, rather than just at the boundary between condition class 1 and 2. A fairly low desired departure (5 percent) was selected for the Subalpine PVT because it was felt to be operationally achievable, would put a large component of the landscape in a maintenance condition, and would achieve habitat objectives for Canada lynx and other species of concern.

Most of the treatments in the Lower Montane sagebrush grass PVT could be accomplished as part of broadcast burning in the adjacent montane forest types or upon implementation of a fire use plan. The objective of 5 percent desired departure was used to calculate the amount of area for treatment to achieve and objective of condition class 1. This may appear quite high compared to the values used by Hann and Strohm (2003). However, one of the operational problems that exist in the Box Creek watershed was the mosaic of Lower Montane with Montane stands that would make it difficult to burn one independently from another. In addition there was the problem in the Montane PVT of the total lack of some of the characteristic early seral and late seral classes with the continuity of the uncharacteristic classes that are a residual pattern from the extensive and intensive mining era logging. This creates a continuous fuel hazard that could be broken up by burning mosaic sagebrush units to create a mosaic of low hazard areas that could be used as black line or green strips. In order to move the whole landscape to a more characteristic mosaic pattern, manage for future recruitment of the late seral open and closed stages, and reduce the severe levels of mistletoe and pine beetle risk, substantial area of both PVTs need to be set in a parallel motion through treatment.

Planning Process

Use of a consistent and systematic approach to the planning framework, data, calculation and classification of natural regime departure and fire regime condition class, and context for restoration design to reduce wildland urban interface risk along with ecosystem and habitat risk, were found to be critical to the project foundation and communication. In particular, the up front interdisciplinary and integrated Upper Arkansas assessment, continuous public involvement with key individuals and groups, Box Creek prioritization, purpose and need, and design of prescriptions and action alternatives avoided the “mitigation spin.”

For any project on federal public lands the actual “decision space” generally falls within an area defined by the intersection of legal/policy limits, operational limits, and some measure(s) of land management objectives (Fig. 12). For this project we will call these measures “fire regime risk” and “urban interface risk.” In Figure 12 this overlap area of decision space has an x-section pattern and is titled “interdisciplinary prioritized design.” If agency leadership directs through policy and education that this integrated approach be implemented then these risks can be substantially reduced (40 to 60 percent). However, during recent history and currently most agency projects eventually end up in the “mitigation spin.” This occurs when the project is prioritized and designed from a narrow, non-interdisciplinary traditional management view, such as from just fire, fuels or timber, to achieve primarily operational and target area considerations, with conceptual statements of risk reduction, but little emphasis on science-based measures of risk. Other disciplines then must react with mitigation to reduce the negative effects to their resource and meet legal and policy requirements. The final mitigated action alternative may often only treat half or less of the proposed treatment, and only reduce the actual science-based risk measure to urban interface and ecosystems by a tenth.

In summary, the results from the Box Creek watershed restoration project demonstrate a cost-effective and science-based attempt to provide consistent and repeatable risk data for assessment of conditions and development of alternatives. In addition, the interdisciplinary team demonstrated how to identify the full “decision space” available for restoration if an integrated approach to project prioritization, purpose and need, and proposed action formulation is implemented versus accepting the “mitigation spin.”

MANAGEMENT IMPLICATIONS

Findings from this project have wide applicability to accomplishment of National Fire Plan, Cohesive Strategy, land management analysis and planning processes, threatened and endangered species conservation strategies, and general land management objectives.

Analysis Process Implications

1) We have demonstrated an interdisciplinary and integrated approach to analysis that provides consistent, science-based measures of fire regime condition class, natural regime departure, wildlife habitat, and other vegetation and resource values that can be used to prioritize projects at multiple scales and to develop a linked purpose and need, action alternatives, and effects analysis.
2) The methods for project and watershed scale fire regime condition class and natural regime departure can be used to determine a landscape scale status, but should not be used at single stand scales. At single stand scales risk ratings of low, high, or moderate should be used to identify the contribution of that stand to overall landscape risk. Management implications of reduce, retain, or recruit can be assigned at the stand scale.
3) This project has demonstrated the value of integrating the set of potential vegetation, cover type, and structure vegetation themes for use by all interdisciplinary team members. This improves accuracy, credibility, and communication during the analysis and planning process.
4) In the Box Creek project area the “textbook” assumption that the lodgepole cover type infers a crown fire replacement regime would have substantially misled the analysis and planning process. Each landscape project is usually unique in its ecosystem or history and deserves on-the-ground investigation.

Planning Process Implications

1) We have demonstrated an interdisciplinary approach to prioritization and design of purpose and need and proposed action that can aggressively achieve action objectives and reduce risk to urban interface, ecosystems, forest health, watershed, and wildlife habitats within operational and legal/policy limitations. This approach has been tested and recommended by a number of other investigations (Quigley et al. 1996, Reiman et al. 2000, Hann and Bunnell 2001, Hann and Strohm 2003).
2) Traditional fire or resource single objective project identification and design that focus on conceptual or philosophical objectives and operational limitations, with little focus on interdisciplinary design to achieve legal/policy requirements or science-based measures for objectives do not have the rationale to garner support, and must either be mitigated or cannot be implemented due to appeals and litigation.
3) A traditional approach results in mitigation that substantially reduces size of treated areas (Fig. 12). Lack of science-based and natural regime rationale combined with legal/policy conflicts result in a loss of credibility with the public, regulatory agencies, and congress.
4) Land management agency leadership currently does not provide the direction, the training, or consistent policy on integrated risk data to support aggressive widespread change in direction that would actually implement interdisciplinary prioritization and design combined with science-based rationale.
5) Without active agency leadership direction to change from the “mitigation spin” to interdisciplinary “decision space” combined with training and an integrated data policy it will be difficult to achieve objectives that require landscape scale restoration to reduce risks to both people and ecosystems.

TABLES

Table 1 - Natural fire regime classes from Schmidt et al. (2002) and Hardy et al. (2001) as interpreted by the authors for modeling landscape dynamics at project and watershed scales.

Fire Regime Class	Frequency (Fire Return Interval)	Severity	Modeling Assumptions
I	0 – 35 years, Frequent	Surface	Open forest or savannah structures maintained by frequent fire; also includes frequent mixed severity fires that create a mosaic of different age post-fire open forest, early to mid-seral forest structural stages, and shrub or herb dominated patches, generally < 40 hectares.
II	0 – 35 years, Frequent	Replacement	Shrub or grasslands maintained or cycled by frequent fire; fires kill non-sprouting shrubs which typically regenerate and become dominant within 10-15 years; fires remove tops of sprouting shrubs which typically resprout and dominate within 5 years; fires typically kill most tree regeneration.
III	35 – 100+ years, Infrequent	Mixed	Mosaic of different age post-fire open forest, early to mid-seral forest structural stages, and shrub or herb dominated patches generally < 40 hectares, maintained or cycled by infrequent fire. Interval can range up to 200.
IV	35 – 100+ years, Less Infrequent	Replacement	Large patches generally > 40 hectares, of similar age post-fire shrub or herb dominated structures, or early to mid-seral forest cycled by infrequent fire. Interval can range up to 200.
V	> 100-200+ years, Rare	Replacement	Large patches generally > 40 hectares, of similar age post-fire shrub or herb dominated structures, or early to mid to late seral forest cycled by infrequent fire.

Table 2 - Condition Classes from Schmidt et al. (2002) and Hardy et al. (2001) as interpreted by the authors for modeling landscape dynamics and departure from historical (natural) range of variability at project and watershed scales. Historical Range of Variability (HRV) is the variability of regional or landscape composition, structure, and disturbances, during a period of time of several cycles of the common disturbance intervals, and similar environmental gradients, referring, for the United States, to a period prior to extensive agricultural or industrial development. Natural Range of Variability (NRV) - the ecological conditions and processes within a specified area, period of time, and climate, and the variation in these conditions that would occur without substantial influence from mechanized equipment (synthesized from Landres et al. 1999, Hann et al. 1997, Morgan et al. 1994).

Class	NRV or HRV Departure	Description
Condition Class 1	Low	Vegetation composition, structure, and fuels are similar to those of the natural regime and do not predispose the system to risk of loss of key ecosystem components. Wildland fires are characteristic of the historical fire regime behavior, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are within the natural range of variability. Smoke production potential is low in volume.
Condition Class 2	Moderate	Vegetation composition, structure, and fuels have moderate departure from the natural regime and predispose the system to risk of loss of key ecosystem components. Wildland fires are moderately uncharacteristic compared to the natural fire regime behaviors, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are outside the natural range of variability.
Condition Class 3	High	Vegetation composition, structure, and fuels have high departure from the natural regime and predispose the system to high risk of loss of key ecosystem components. Wildland fires are highly uncharacteristic compared to the natural fire regime behaviors, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are substantially outside the natural range of variability.

Table 3. Box model class descriptions from Hann (2002 *this volume*) with additional description and interpretations.

Class	Process	Forest & Woodland	Shrubland & Grassland
A	Characteristic; post-replacement disturbance; early development	Single layer; < 5 % tree canopy cover; standing dead	Fire response forbs; resprouting shrubs & grasses
B	Characteristic; mid successional; competition stress; closed canopy	One to 2 upper layer size classes; > 40% canopy cover; litter/duff; standing dead and down	Upper layer young shrubs or grasses; > 15% canopy cover
C	Characteristic; mid successional; disturbance maintained; open	One size class in upper layer; < 40% canopy cover; fire-adapted understory; scattered standing dead and down	Upper layer young shrubs or grasses; < 15% canopy cover
D	Characteristic; late successional; disturbance maintained; open	Single upper canopy tree layer; 1 to 3 size classes in upper layer; < 40% canopy cover; fire-adapted understory; scattered standing dead and down	Upper layer mature shrubs or grasses; < 15% canopy cover
E	Characteristic; late successional; competition stress; closed	Multiple upper canopy tree layers; multiple size classes; > 40% canopy cover; shade- tolerant understory; litter/duff; standing dead and down	Upper layer decadent shrubs or grasses; > 15% canopy cover
I	Uncharacteristic succession; natural disturbance frequency is beyond maximum	Usually associated with change to larger patch size and loss of patch mosaic with more contiguous heavy fuels	Usually associated with change to larger patch size and loss of patch mosaic with more contiguous fuels
H	Uncharacteristic grazing management; grazing season, frequency, and intensity is not similar to natural regime	Often associated with loss of shrub and grass understory; spread of invasive weeds	Decrease in desirable forage species; increase in less desirable and invasive species
G	Uncharacteristic timber management; timber harvest, stand improvement, and tree planting is not similar to natural	Large trees harvested & small trees remain; systematic tree spacing; planting higher density or different species composition than natural.	
L	Uncharacteristic insect-disease; invasive insects or disease, such as blister rust; epidemic or level of extent not similar to natural	Occurs following uncharacteristic timber harvest of large trees leaving susceptible trees	
F	Uncharacteristic invasive plants; difficult to reverse with restoration if large and scattered infestations; most effective to prevent and contain	Along roads and in harvest units with mechanical soil surface disturbance; more competitive than native grasses and forbs	Commonly spread by livestock; more competitive than native plants; usually associated with increase (annual grasses) or decrease (knapweed) in fire frequency
J	Uncharacteristic fire effects; effects of fire on ecosystem more severe than natural; difficult to reverse with restoration; most effective to restore before this occurs	Occurs in areas with excess contiguous fuels; loss of large trees, excessive smoke, soil erosion, increased water temperatures	Occurs in areas with contiguous upper layer fuels due to uncharacteristic succession or invasive plants
K	Uncharacteristic soil disturbance; loss of soil at higher rates than natural regime; cannot be effectively restored	Commonly occurs following severe fire effects, hydrophobic soils, and mechanical disturbance	Commonly occurs in woodlands (such as juniper) when lose soil cover; excessive grazing; invasive plants

Table 4. Descriptions of cover types and structures for the Box Model classes that currently occur in the Mountain Montane potential vegetation type of the Box Creek watershed.

Class	Box Model Name	Cover Type 1	Cover Type 2	Cover Type 3	Cover Type 4
A	Characteristic; post-replacement; early development	LP, DF, PP; shrub tree seedling herb	PP; shrub tree seedling herb	QA, CO; shrub tree seedling herb	
B	Characteristic; mid development; closed	QA, CO; Pole-sapling tree closed			
C	Characteristic; mid development; open	LP, DF, PP; Pole-sapling tree open	LP, DF, PP; pole-sapling tree moderate	QA, CO; pole-sapling tree moderate	PP; Pole-Sapling Tree Moderate
D	Characteristic; late development; open	LP, DF, PP; mature tree open	PP; mature tree open and moderate	PP; old tree	QA_CO Mature Tree Moderate
E	Characteristic; late development; closed	QA, CO old tree	LP, DF, PP; old tree		
G	**Uncharacteristic timber management not mimicking natural regime**	LP; shrub tree seedling herb clearcut with no PP or DF regeneration			
I	Uncharacteristic succession	LP; mature tree moderate with very deep litter/duff & excessive down fuels			
L	Uncharacteristic insect-disease invasive or more severe	LP; pole-sapling closed, moderate, & open with severe mistletoe	LP; mature tree closed, moderate, & open with severe mistletoe		

DF – Douglas-fir
LP – lodgepole pine
PP – ponderosa pine
QA – quaking aspen
CO – conifer

Closed - ≥ 60% canopy cover
Moderate - ≥ 40% and < 60% canopy cover
Low - < 40% canopy cover

Table 5. Descriptions of cover types and structures for the Box Model classes that currently occur in the Mountain Subalpine potential vegetation type of the Box Creek watershed.

Class	Box Model Name	Cover Type 1	Cover Type 2	Cover Type 3	Cover Type 4
A	Characteristic; post-replacement; early development	ES, SA; shrub tree seedling herb	LP; shrub tree seedling herb	QA, CO; shrub tree seedling herb	
B	Characteristic; mid development; closed	LP; pole-sapling closed	QA, CO; pole-sapling closed	ES, SA; pole-sapling closed	
C	Characteristic; mid development; open	LP; pole-sapling moderate	LP; mature tree moderate	LP; mature tree open	QA, CO; pole-sapling moderate & open
D	Characteristic; late development; open	QA, CO; mature tree open	LP; mature tree moderate		
E	Characteristic; late development; closed	QA, CO; old tree	QA, CO; mature tree moderate	QA, CO; mature tree closed	LP; old tree
I	Uncharacteristic succession	LP or ES, SA; mature tree closed with very deep litter/duff & excessive down fuels			

Cover type tree species
DF – Douglas-fir
LP – lodgepole pine
PP – ponderosa pine
QA – quaking aspen
CO – conifer
ES – Engelman spruce
SA – subalpine fir

Canopy closure classes
Closed - $\geq$ 60% canopy cover
Moderate - $\geq$ 40% and < 60% canopy cover
Low - < 40% canopy cover

Tree size classes
Seedling – Trees < 1.37 m tall
Sapling – Trees $\geq$ 1.37 m tall and < 13 cm dbh
Pole – Trees $\geq$ 13 cm dbh and < 23 cm dbh
Mature – Trees $\geq$ 23 cm and < 53 cm dbh
Old – Trees $\geq$ 53 cm dbh

Table 6. Comparison of current to historical for the Mountain Montane potential vegetation type with summary of current similarity, percent difference, restoration implication, and risk of uncharacteristic fire and habitats

Box Model Class	Historical (Natural) Regime Average	Current Amount	Current Similarity	Percent Difference (Current-Historical)/ Historical	Current Restoration Implication	Current Risk to Ecosystems
A	8	0	0	-100	Recruit	High
B	2	4	2	- 50	Reduce	Moderate
C	16	1	1	+100	Retain-Recruit	High
D	66	7	7	- 90	Retain-Recruit	High
E	8	0	0	-100	Recruit	High
G	NA	7	0	NA	Reduce	High
I	NA	11	0	NA	Reduce	High
L	NA	70	0	NA	Reduce	High
	100	100	10			

NA – Not Applicable because not present during historical (natural) regime.
Current Departure = 100 – Current Similarity = 100-10 = 90%
Amount of Characteristic Stand Conditions = 0+4+1+7+0=12%
Amount of Uncharacteristic Stand Conditions = 7+11+70=88%

Table 7. Comparison of current to historical for the Mountain Subalpine potential vegetation type with summary of current similarity, percent difference, restoration implication, and risk of uncharacteristic fire and habitats

Box Model Class	Historical (Natural) Regime Average	Current Amount	Current Similarity	Percent Difference (Current-Historical)/ Historical	Current Restoration Implication	Current Risk to Ecosystems
A	12	0	0	-100	Recruit	High
B	16	65	16	+189	Reduce	High
C	13	16	13	+ 63	Reduce	High
D	12	0	0	-100	Recruit	High
E	47	11	11	- 74	Retain-Recruit	High
I	NA	7	NA	NA	Reduce	High
	100	100	40			

NA – Not Applicable because not present during historical (natural) regime.
Current Departure = 100 – Current Similarity = 100 – 40 = 60%
Amount of Characteristic Stand Conditions = 0+65+16+0+11=93%
Amount of Uncharacteristic Stand Conditions = 7=7%

Table 8. Summary of Box Creek watershed potential vegetation types and area to restore.

Potential Vegetation Type	Indicator Species	Area (ha)	Current Departure %/ Desired Departure	Fire Regime Condition Class Current/Desired	Natural Regime Departure Class Current/Desired	Desired Departure	Amount to Treat to Restore to Condition Class 1 (ha)
Mountain Montane	lodgepole pine, ponderosa pine, Douglas-fir	2,306	90/20	Frequent Mixed Condition Class 3/1	H/L	20	1,615
Mountain Subalpine	Engelman spruce, subalpine fir, lodgepole pine	1,414	60/5	Infrequent Mixed Condition Class 2/1	M/L	5	778
Lower Montane	Mountain Big Sagebrush	3,117	35/5	Frequent Replacement Condition Class 1/1	L/L	5	935
Alpine	Tundra Species	334	5/5	Rare Mixed Condition Class 1/1	L/L	5	0
Riparian	Willows	374	5/5	Infrequent Replacement Condition Class 1/1	L/L	5	0
Total		7,544					3,328

Departures estimated at about 35% for lower montane and 5% for alpine and riparian based on field reconnaissance.
Desired departure of 20% selected for Mt. Montane to restore condition class 3 to 1.
Desired departure of 5% selected for Mt. Subalpine, and Lower Montane to restore condition class 2 to 1.
Desired departure of 5% selected for Alpine and Riparian. No restoration required.
Amount to Treat = ((Current Departure – Desired Departure)/100) * Area

Table 9. Summary of the 24 prescriptions developed for the Box Creek restoration plan.

Rx	Spp	Size	Desired Future Condition	Treatment Prescription	Tool
1	LP	MT	Candidate old growth	Thin to advance structure. Retain largest diameter size classes & all snags >30.5 cm dbh	H/NH
2	LP	SA	Lodgepole pine	Sanitize if needed; protect advanced growth	H/NH
3	LP	SA	Mixed conifer	Sanitize if needed; plant with DF/PP; protect advanced growth	H/NH
4	LP	SA	Mixed conifer	Sanitize for mistletoe; thin to 618 trees/ha; plant with DF/PP; protect advanced growth	H/NH
5	LP	PT	Candidate open mature/old	Thin; protect advanced structural stage	H/NH
6	LP	PT	Candidate mature/old	No thinning; protect advanced structural stage	H/NH
7	LP	PT	Sanitize for mistletoe	Sanitize; thin	F/H/NH
8	LP	PT	Aspen	Regenerate	F/H/NH
9	LP	PT	Seedling spruce; lynx habitat, spruce size class diversity	Regenerate; no thinning of conifer regeneration until crowns are 1.8 m above ground (lynx foraging habitat)	F/H/NH
10	LP	PT	DMT control for regeneration	Regenerate	F/H/NH
11	LP	PT	Ponderosa pine, open, mature, fire maintained	Remove lodgepole pine understory; retain all ponderosa pine without mountain pine beetle larvae; retain all snags > 30.5 cm dbh	F/H/NH
12	LP	PT	Big game forage; conversion to winter range; enhance aspen	Reduce basal area to 1.9 – 11.2 m^2 basal area; remove < 30.5 cm lodgepole; maintain open understory with periodic fire; plant ponderosa pine in micro sites (optional)	F/H/NH
13	LP	PT	Burned snag patches	Mixed severity fire; mechanical pre-treatment; no post burn removal of burned trees	F
14	LP	Any	Mixed conifer	Reduce lodgepole to encourage other conifer; maintain thermal & security cover	H/NH
15	AC	Any	Aspen conifer mix	Protect where possible	None
16	AC	Any	Young age class; aspen clones	Regenerate; if using fire, follow historic burn pattern	F/H/NH
17	ES	OT	Old growth	Protect	None
18	ES	MT	Candidate old growth	Retain	None
19	ES	Any	Seedling spruce, spruce size class diversity; cavity nesters	Regenerate; no thinning of conifer regeneration until crowns are 1.8 m above ground (lynx foraging habitat); follow historic burn pattern; retain all burned snags	F
20	ES	Any	Aspen expansion	Regenerate aspen	F/H/NH
21	SB	Any	Maintain early seral stage	Regenerate	F
22	Any	Any	Not Applicable	None	None
23	Any	Any	WUI maintain condition class 1 fuel break; control DMT & MPB	Retain larger diameter size class; treat activity fuels pile/burn or lop & scatter; minimum 274 m fuel break where possible; sanitize for DMT and MPB where possible	H/NH
24	Any	Any	Variable	Retention	None

<u>Species Code</u>	<u>Tree Size Code</u>	<u>Tool Code</u>	<u>Other Codes</u>
LP – lodgepole pine	MT – mature	F – fire	BA basal area
ES – Engelman spruce	SA – sapling	H – harvest	DBH – diameter breast height
DMT – dwarf mistletoe	PT – pole	NH – noncommercial thin	WUI – wildland urban interface

Table 10. Summary of alternatives designed for restoration of the Box Creek watershed.

Tools	Alternatives (ha)			
	No Action	Proposed Action	Harvest Emphasis	Fire Emphasis
Fire	0	2,021	1,815	2,754
Harvest	0	1,073	1,328	141
Protect	0	404	404	404
Maintain	235	235	235	235
No Treatment	7,314	3,815	3,766	4,015
Total Area	7,549	7,548	7,548	7,549

Figures

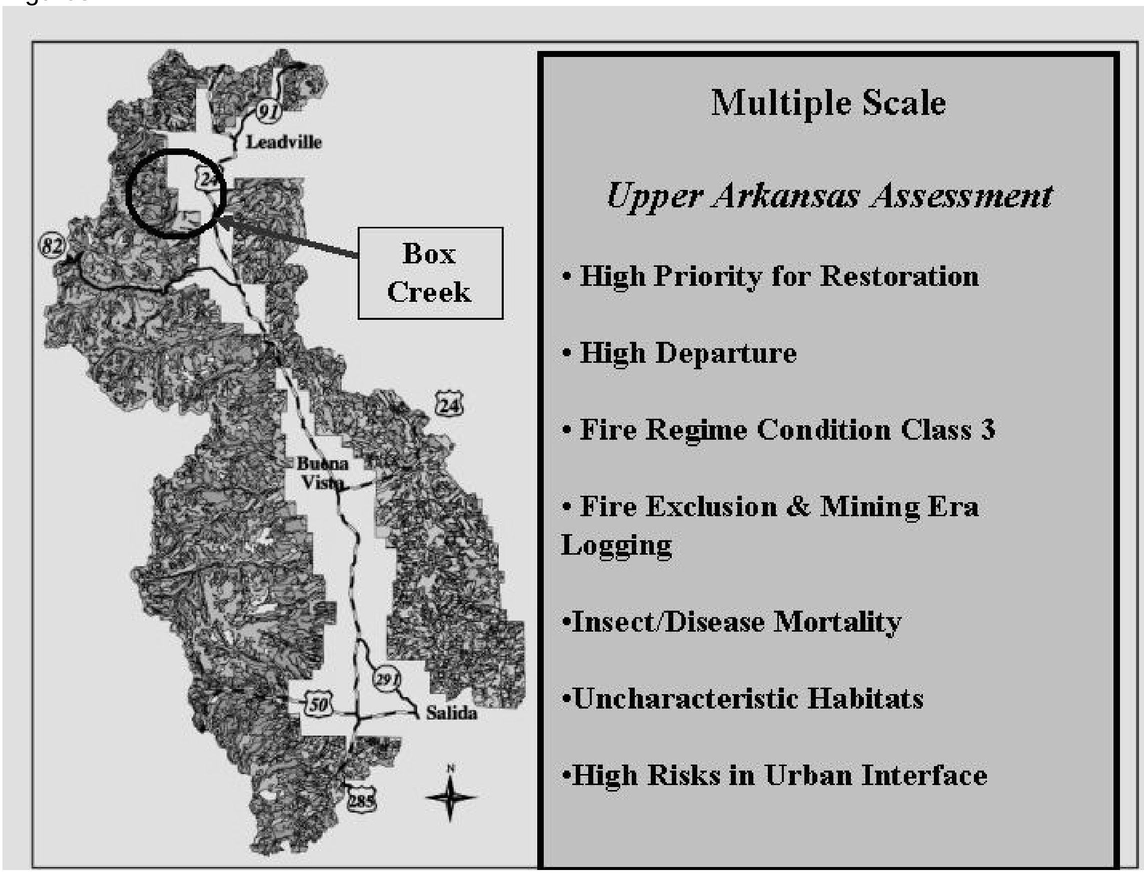

Figure 1. Map of Upper Arkansas assessment indicating Box Creek watershed has a high priority for restoration based on high departure from the historical (natural) regime, high risk fire regime (condition class 3), uncharacteristic levels of insect and disease, uncharacteristic wildlife habitats, and high wildfire risk to the wildland urban interface. Much of the departure and uncharacteristic conditions result from the combination of mining era (late 1800s and early 1900s) logging and wood cutting combined with fire exclusion.

Figure 2. Picture of the Box Creek watershed looking from the east with Mt. Elbert on the left (south) and Halfmoon Creek and the southern ridge of Mt. Massive on the right (north). Picture is warped to emphasize elevation and aspect differences. Lower southerly slopes, benches and ridges are sagebrush/grass, lower northerly slopes and mid elevation ridges, benches and slopes are mixed conifer, upper elevation timbered slopes are subalpine fir and spruce, with the alpine meadow and rock zone above.

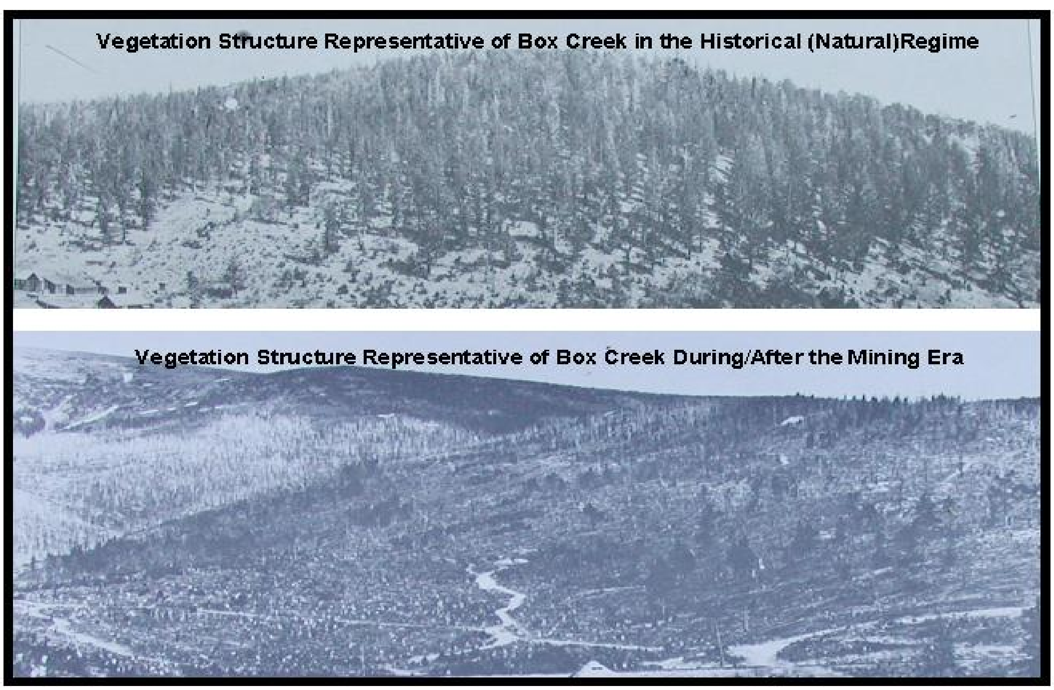

Figure 3. Comparison of what a landscape view of Box Creek types of vegetation and fire regimes may have looked like during the historical (natural) regime as compared to during and after the mining era. These can be compared to the current landscape view shown in figure 2. Historical photos from Veblen and Lorenz 1991.

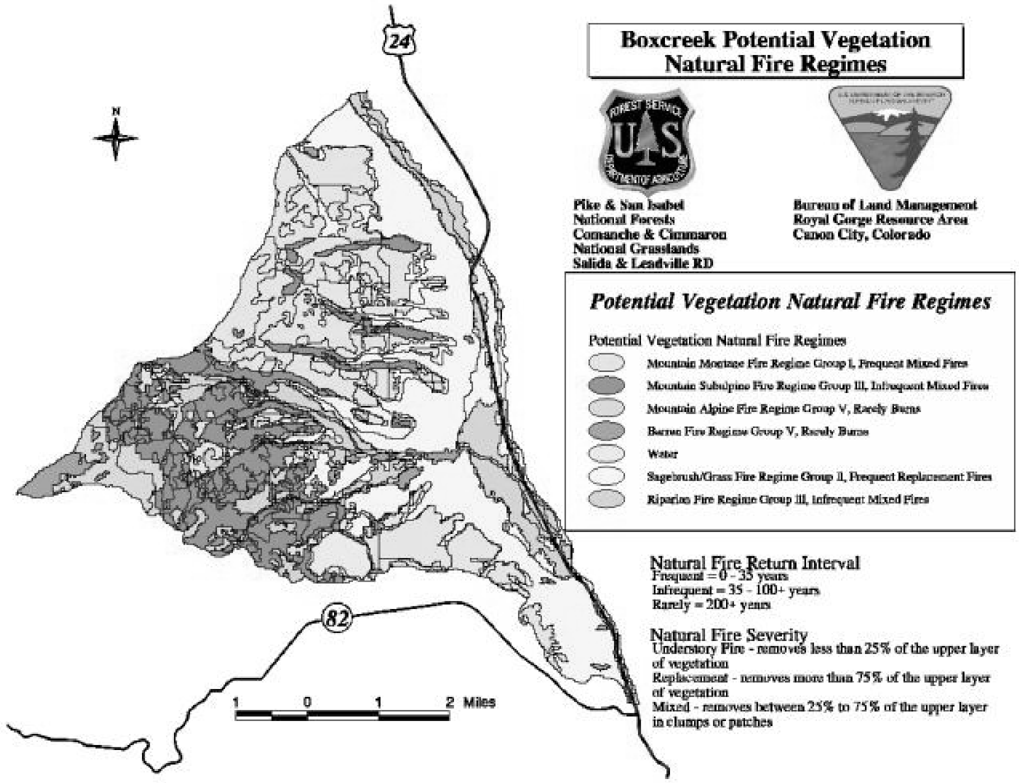

Figure 4. Potential vegetation types for the Box Creek watershed. Potential vegetation types were mapped through combination of use of landtype mapping with current cover type maps and ground truth. Potential vegetation is the endpoint of succession usually named by the understory tree, shrub, and herbaceous species that best indicate the moisture, temperature, and soil regime. For example, presence of subalpine fir in the understory of a lodgepole pine-spruce cover type would indicate the mountain subalpine potential vegetation, rather than mountain montane potential vegetation.

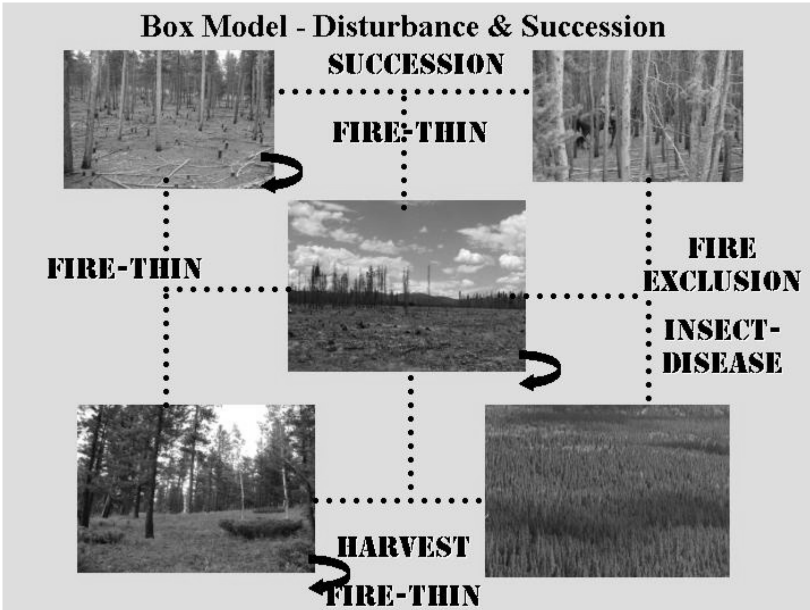

Figure 5. Framework of succession and disturbance computer model used for modeling historical (natural) average and range of variability for vegetation and fire regimes in the Box Creek watershed. Successional times between classes and probabilities of disturbance were developed from ground sampling, review of the literature, and expert judgment.

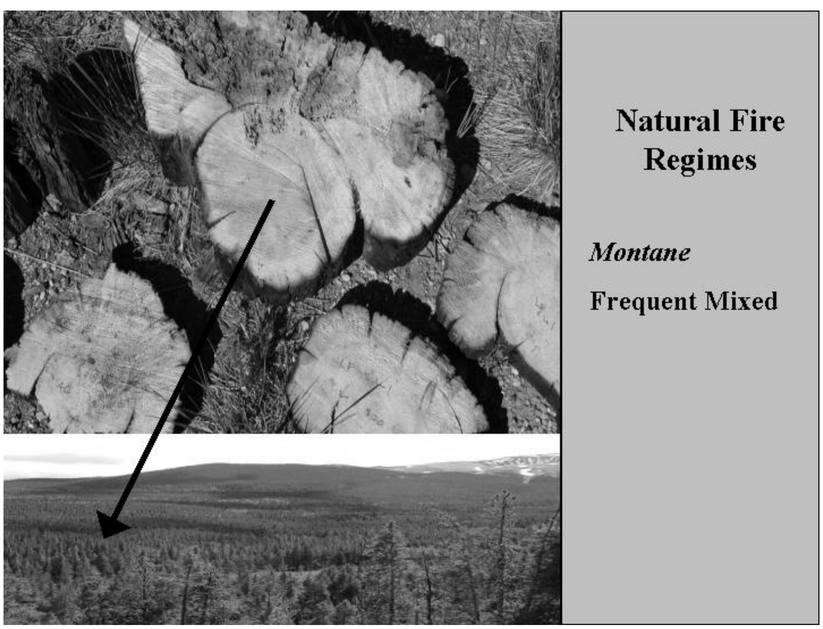

Figure 6. On the ground reconnaissance was used to estimate historical (natural) vegetation composition based on stumps, root wads, and logs of ponderosa pine, Douglas-fir, and lodgepole pine in the mountain montane potential vegetation type. Fire scars from stumps indicated that frequent small fires with mixed surface and small tree group torching maintained an open (1 large tree per acre or less in groups with large open spaces between groups) single layer structure with a productive layer of grass, forbs, and low to moderate height shrubs.

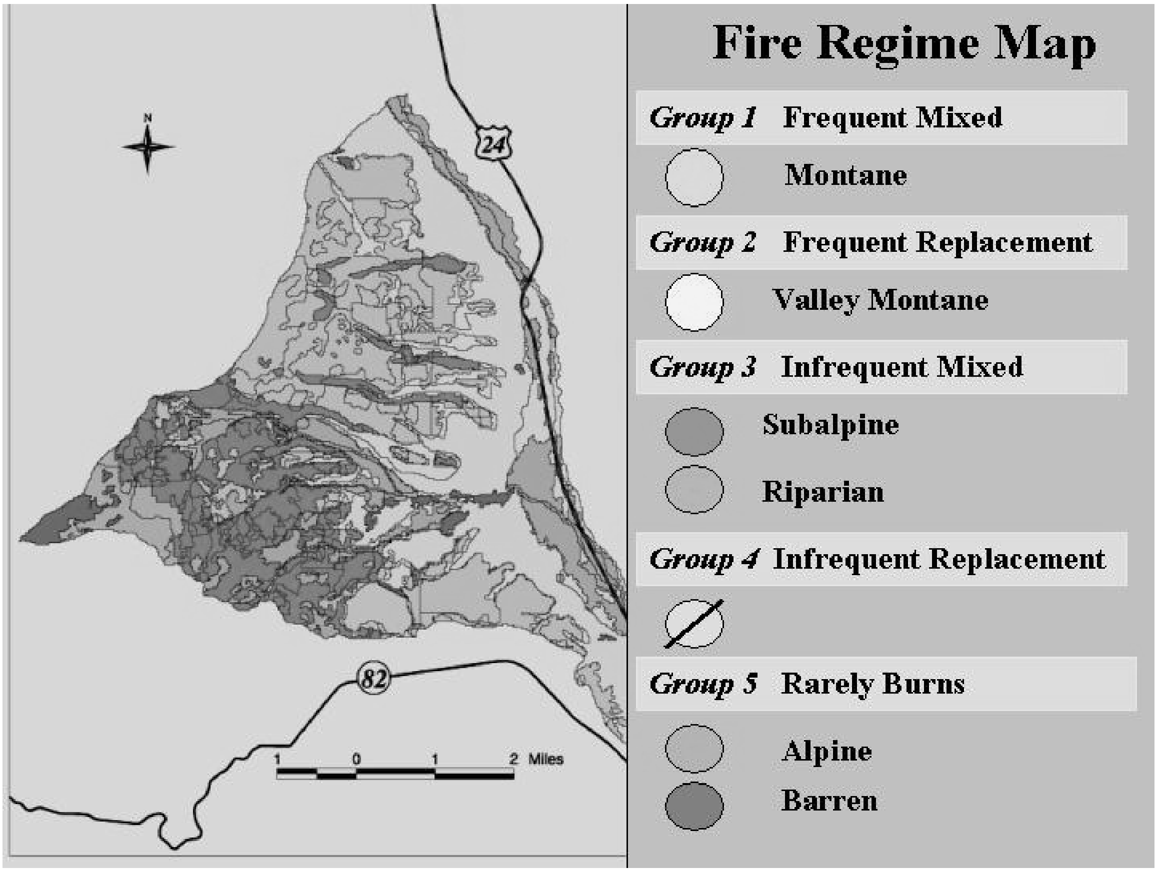

Figure 7. Map of fire regimes developed from the combination of ground reconnaissance, potential vegetation mapping, and succession and disturbance modeling. Preliminary expert judgment, the literature, and the coarse-scale fire regime mapping (Hardy et al. 2001, Schmidt et al. 2002) indicated a predominance of infrequent replacement regime typical for lodgepole pine. On the ground reconnaissance resulted in findings that the historical (natural) vegetation was mixed conifer (ponderosa pine-Douglas-fir-lodgepole pine) with a frequent mixed fire regime.

Figure 8. Desired future conditions for the Box Creek Watershed were based on reducing uncharacteristic wildfire (shifting current crown fire to surface-mixed fire behavior), changing forest structure and composition, reducing risk to urban wildland interface, and restoring habitats (creating black snags for woodpeckers and nesting holes for bluebirds).

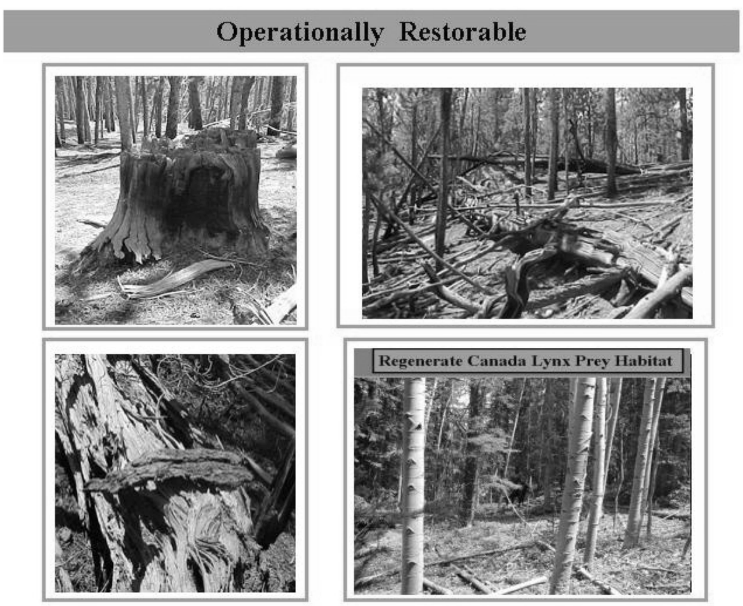

Figure 9. Operationally restorable stands and treatments were identified and designed to achieve the desired future conditions. This included initiating succession to increase composition of large ponderosa pine and Douglas-fir in the mountain montane type. In addition, snags and down wood were retained in the surface-mixed fire regime, while thick lodgepole with heavy down fuels (fuel model 10) were managed to initiate early seral regeneration. An important component of restoration was identifying and designing the restoration of Canada lynx prey (snowshoe rabbits and red squirrels) habitat. Through an interdisciplinary approach this was accomplished in a way that resulted in the treatment of more area for restoration than originally designed based on traditional fire and timber management objectives.

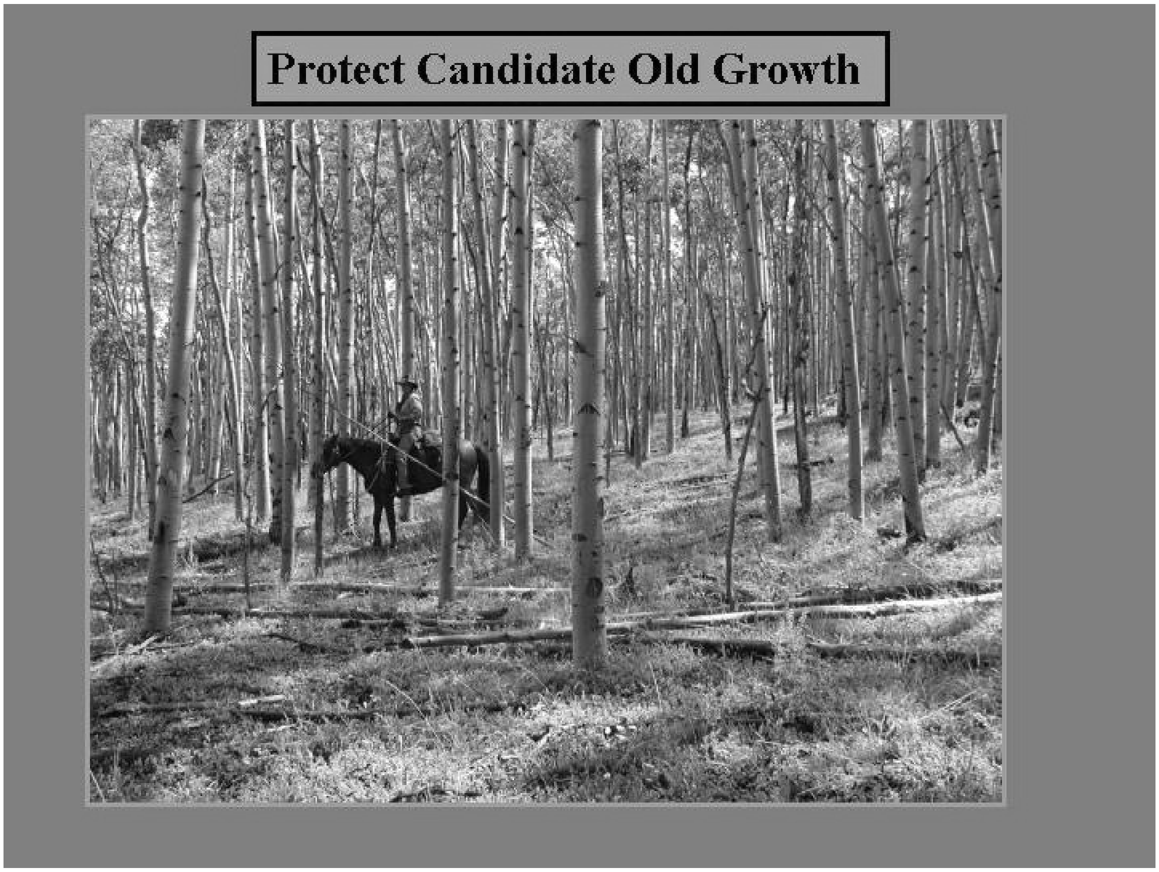

Figure 10. An important treatment was the design of protection options to assure that candidate old forest aspen stands, as well as other types of characteristic old forest conditions, were retained since they were at low levels compared to the historical (natural) regime.

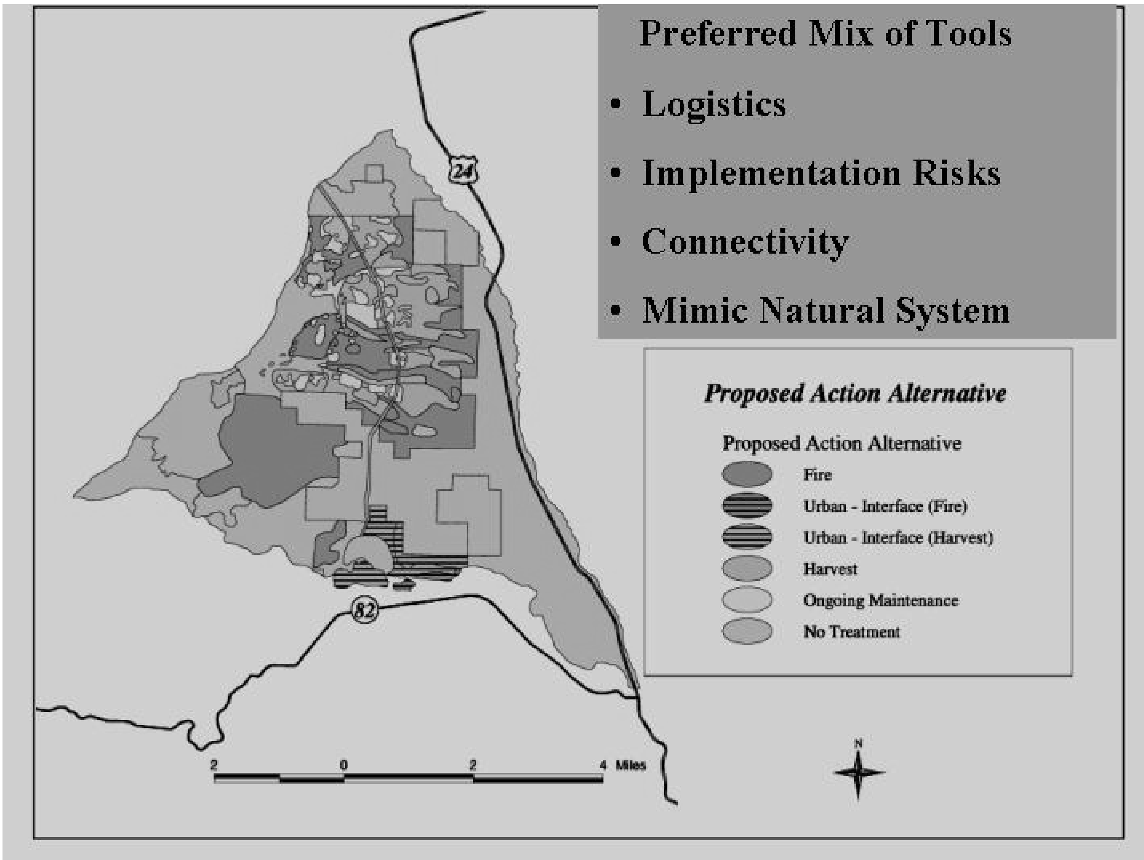

Figure 11. Treatment tools were identified for stands that were operationally restorable based on consideration of current conditions, access, soils, fuel hazards, historical (natural) regime departure, fire regime condition class, urban interface risk, and uncharacteristic habitat conditions.

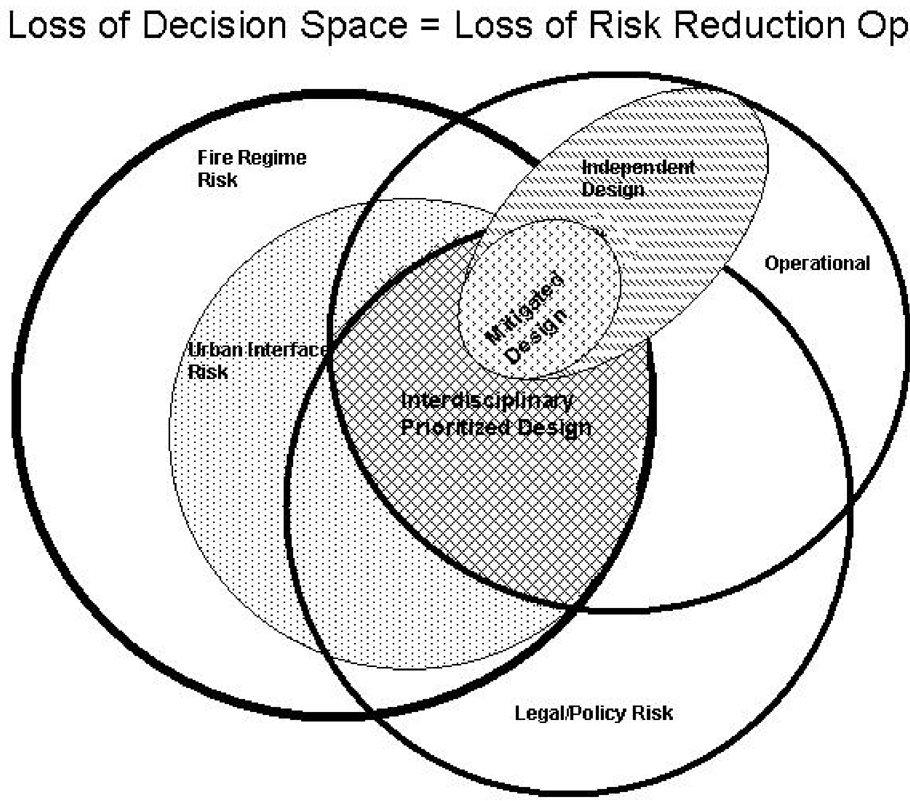

Figure 12. Decision space available for operational restoration to reduce risk of uncharacteristic disturbances (such as wildfire, insect, and disease) to the wildland urban interface and ecosystems (fire, fuels, resources) is lost as a result of lack of up front interdisciplinary prioritization, identification of the project purpose and need, and project design. The intersection of the operational space with the natural regime departure that contributes to urban interface and ecosystem risk with the legal/policy constraints identifies the decision space that an interdisciplinary team can prioritize and design within. This decision space is substantially reduced when traditional fire and timber management projects are designed primarily to achieve operational and traditional objectives without up front integration of legal/policy, reference to the natural regime, and science-based risk measures.

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